Polarimetric radar signatures of deep convective processes observed during MC3E

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Radar observations

Scanning radar gives best spatial and temporal coverage of cloud and precipitation features

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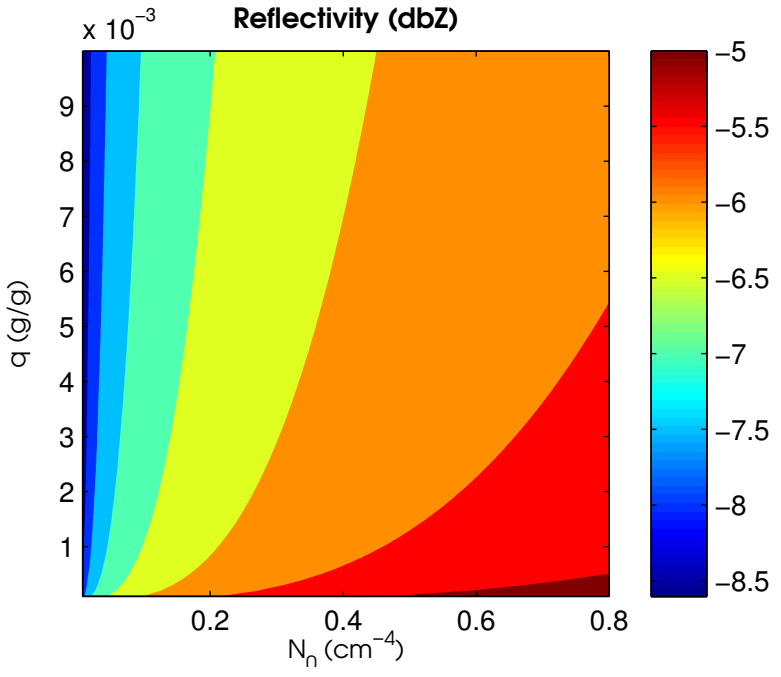
- Microphysical processes

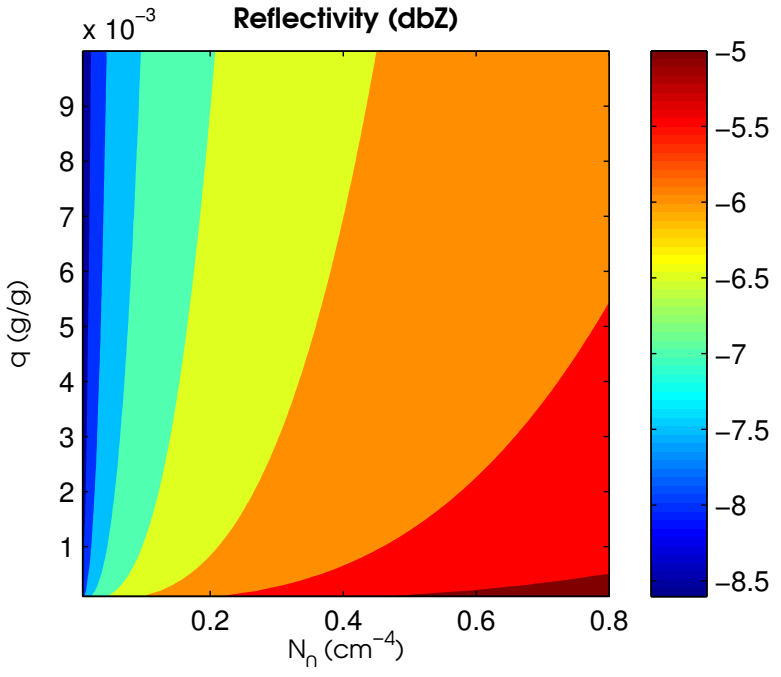
Problems with radar

- Non-unique relationship between radar reflectivity, particle size and number concentration



Problems with radar

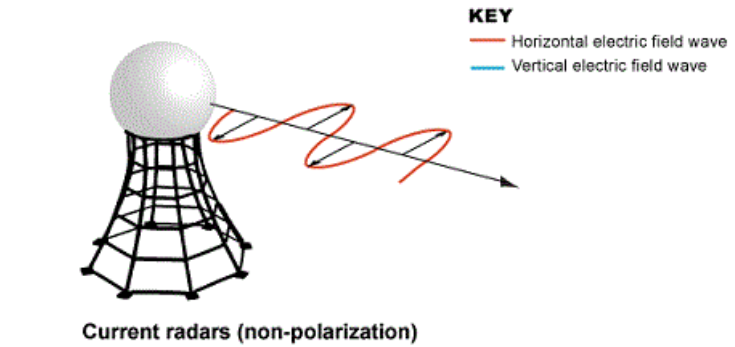
- Non-unique relationship between radar reflectivity, particle size and number concentration
- Additional parameters: particle shape, particle composition, canting angle, roughness



Polarimetric radar

Main idea

Transmit and receive both horizontally and vertically polarized radar waves



Source: NATIONAL WEATHER SERVICE WEATHER FORECAST OFFICE

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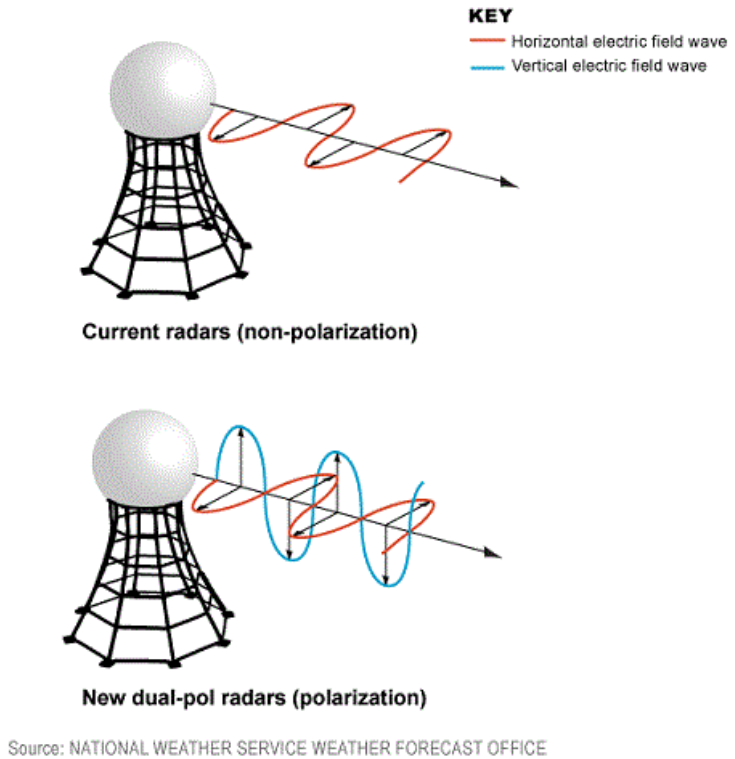
Transmit and receive both horizontally and vertically polarized radar waves

- Compare returned horizontal and vertical signals



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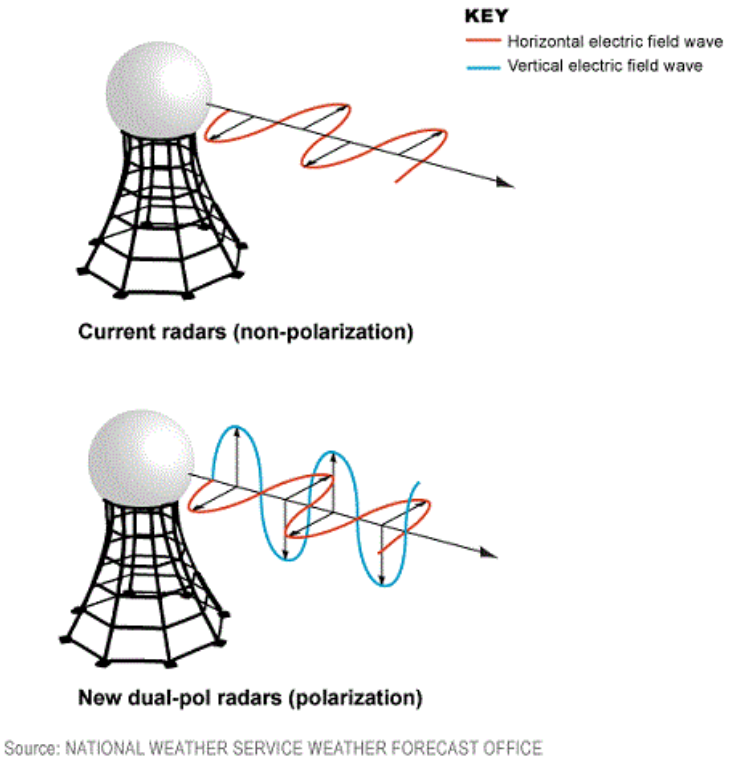
- Provides information on shape/cant/phase, etc.



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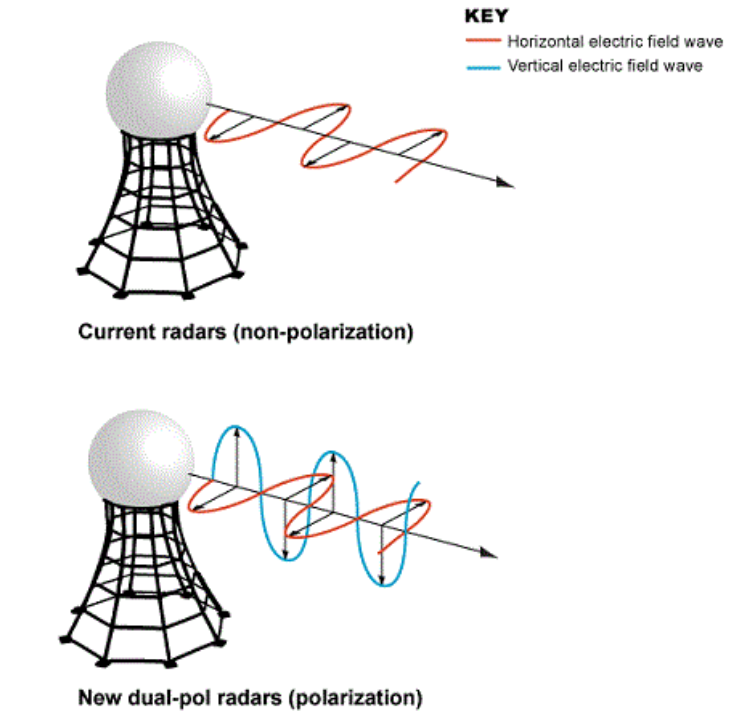
- NWS NEXRAD radar network completed polarimetric upgrade in 2013



Rain shape variations

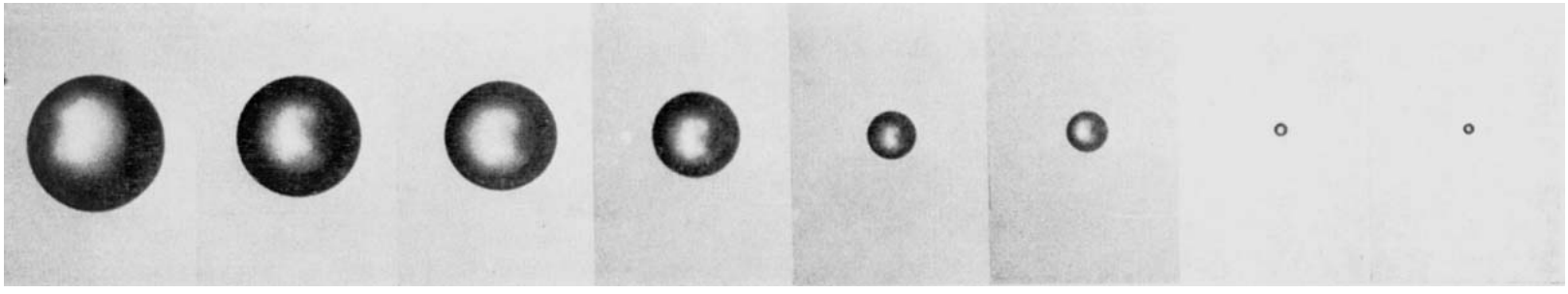


Figure 3. Typical shape of small water drops falling at terminal velocity (from left to right a_0 : 432, 393, 354, 282, 155·5, 130·9, 44·5, 35·8 μm corresponding to the following values for V_∞ : 351, 319, 289, 229, 119, 98, 21, 14 cm s^{-1}.

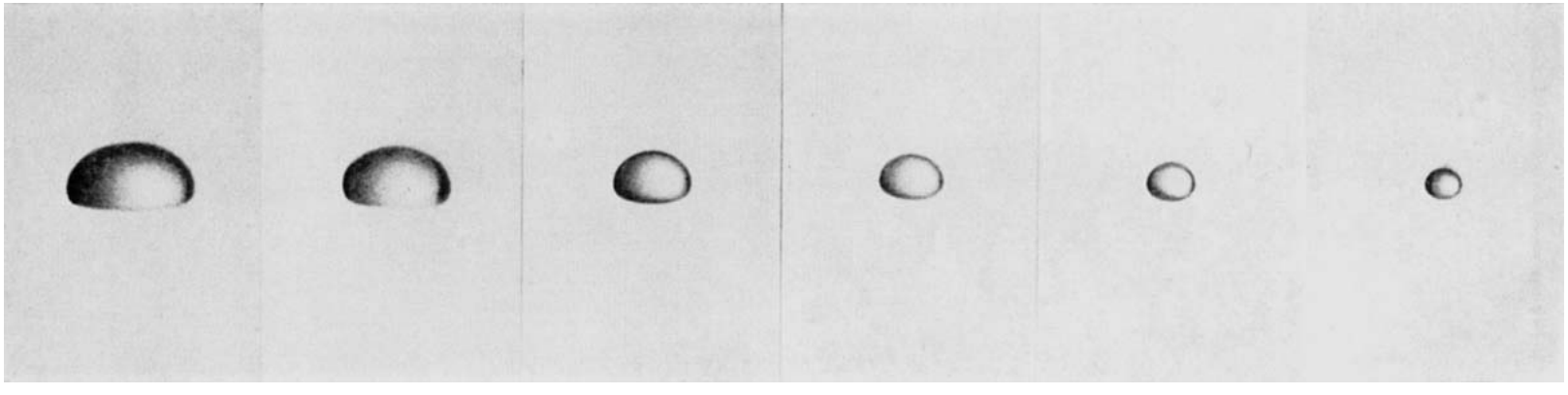


Figure 5. Typical shape of large drops falling at terminal velocity (from left to right a_0 : 4·00, 3·675, 2·90, 2·65, 1·**725, 1·35 mm** corresponding to the following values for V_∞ : 920, 920, 917, 913, 846, 770 cm s^{-1}.

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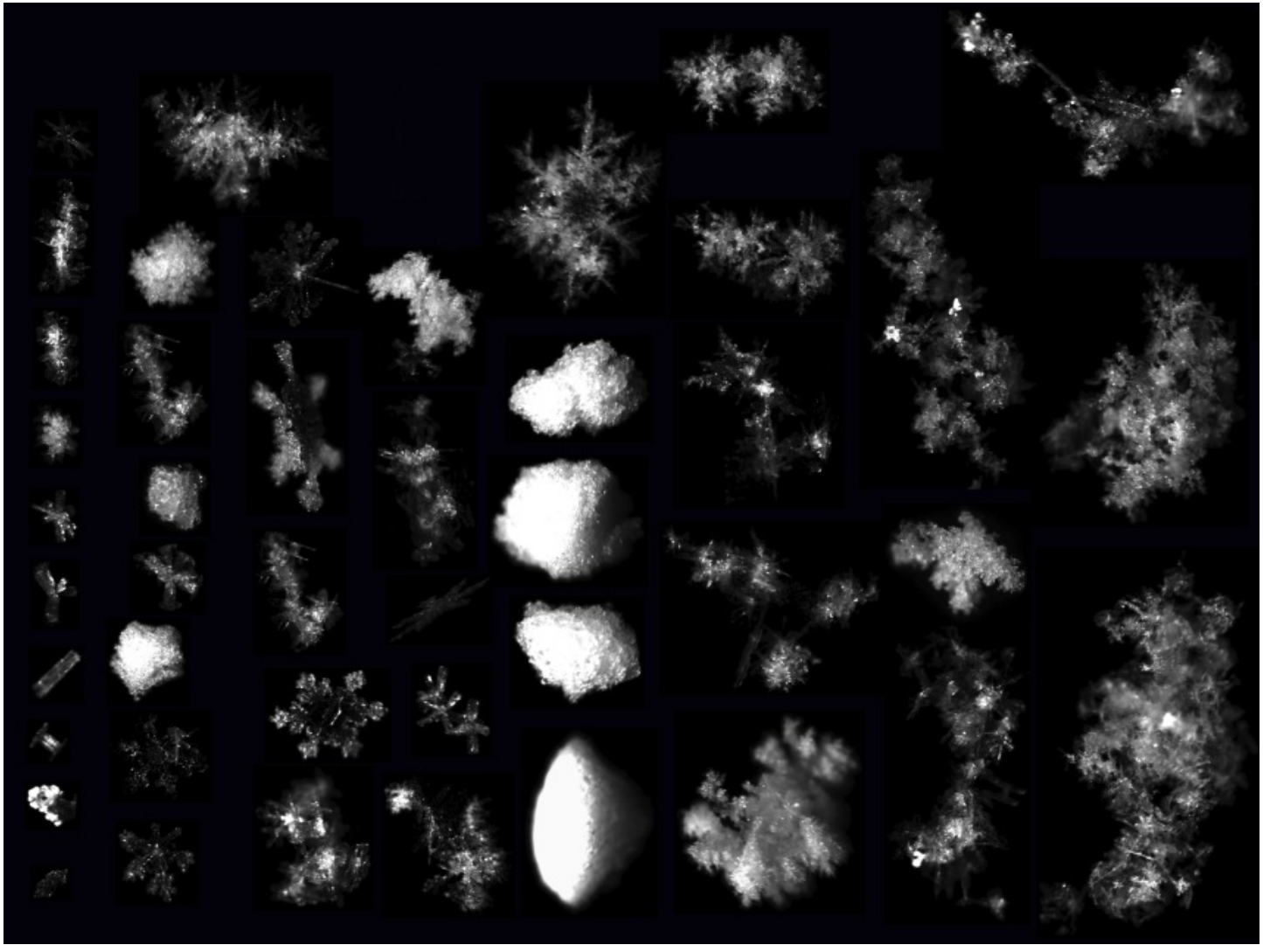
From Pruppacher & Beard (QJRMS 1970).

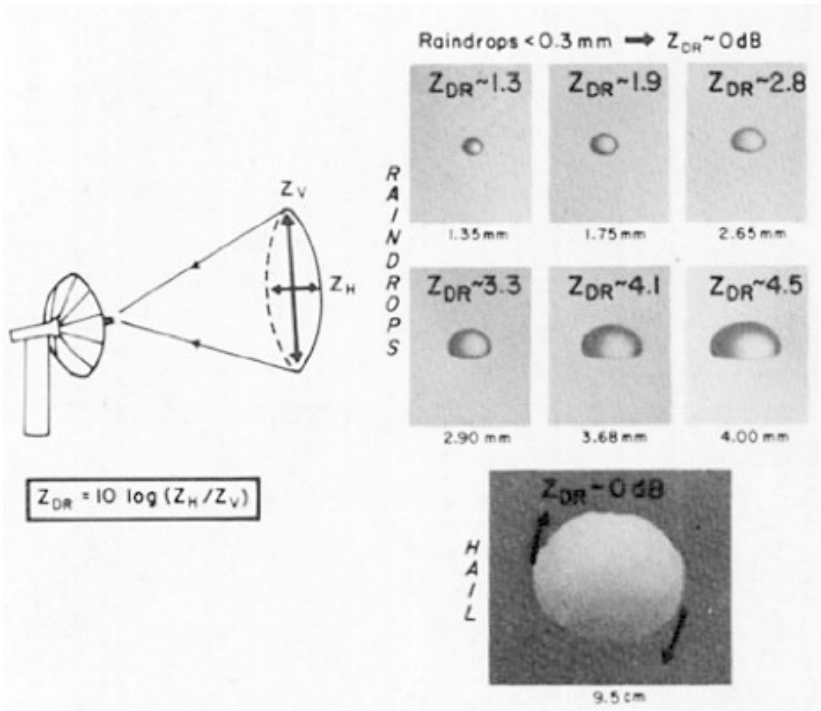
Ice habit diversity



Polarimetric variables – ZDR

Differential reflectivity

$$Z_{DR} = 10 \log_{10}(z_{hh}/z_{vv})$$



From Wakimoto & Bringi (Monthly Weather Review 1988).

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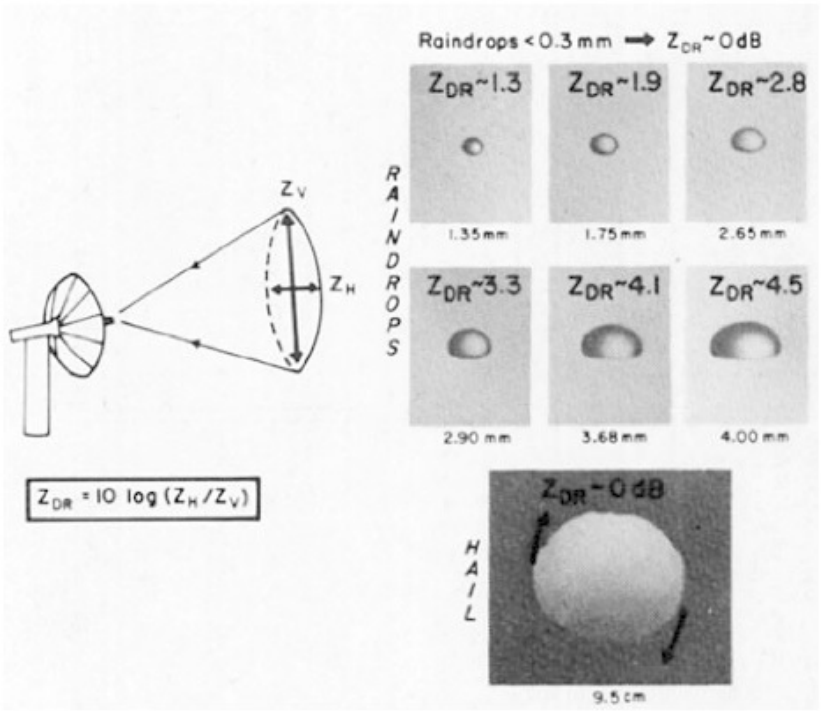

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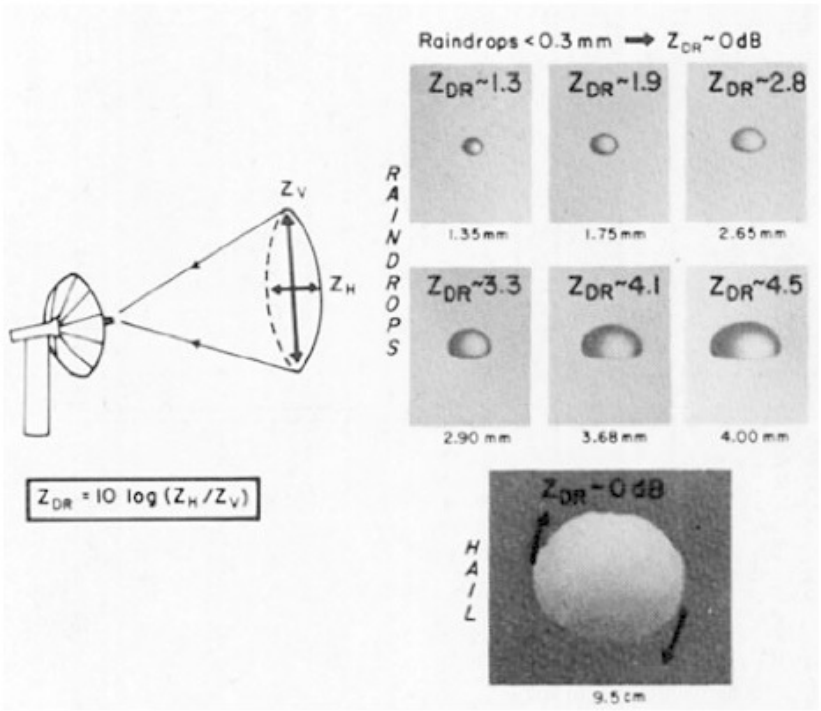

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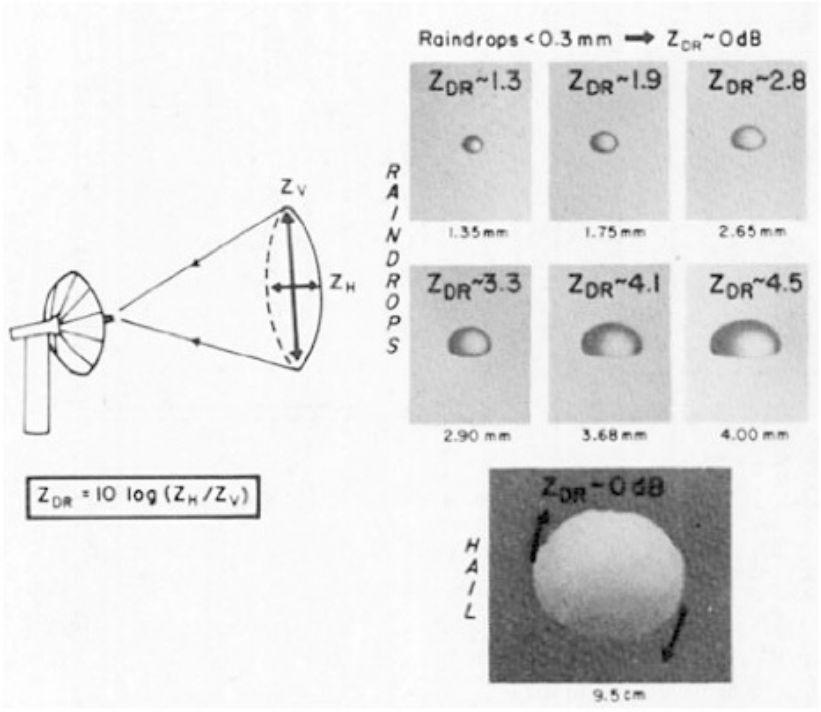
- Insensitive to concentration
- Strongly affected by attenuation (important for C-, X-band)



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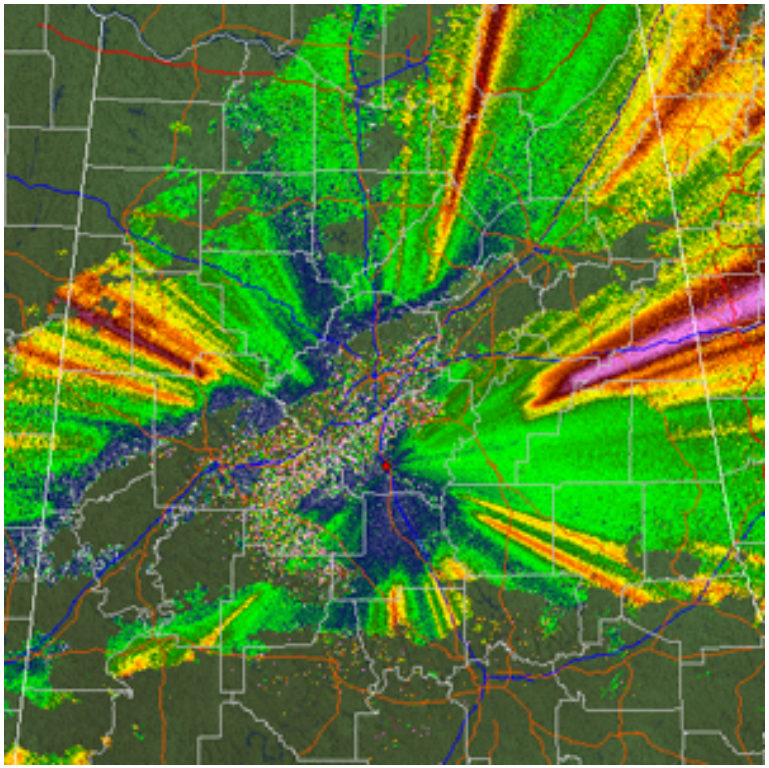
Polarimetric variables – Φ_{DP} & K_{DP}

Differential Phase (Φ_{DP})& Specific Differential Phase (K_{DP})

Difference in phase shift between horizontal and vertical signals

Φ_{DP}



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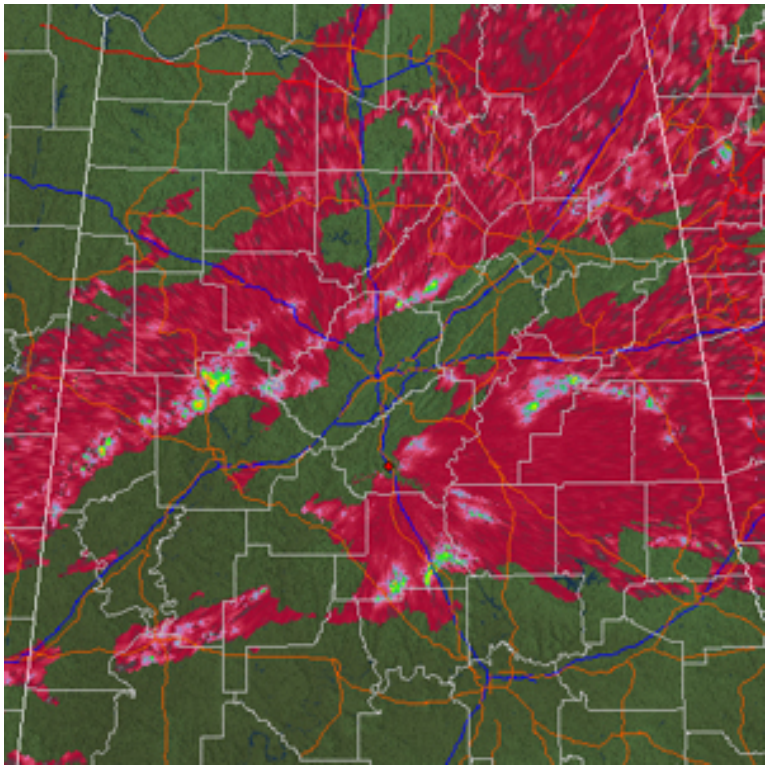

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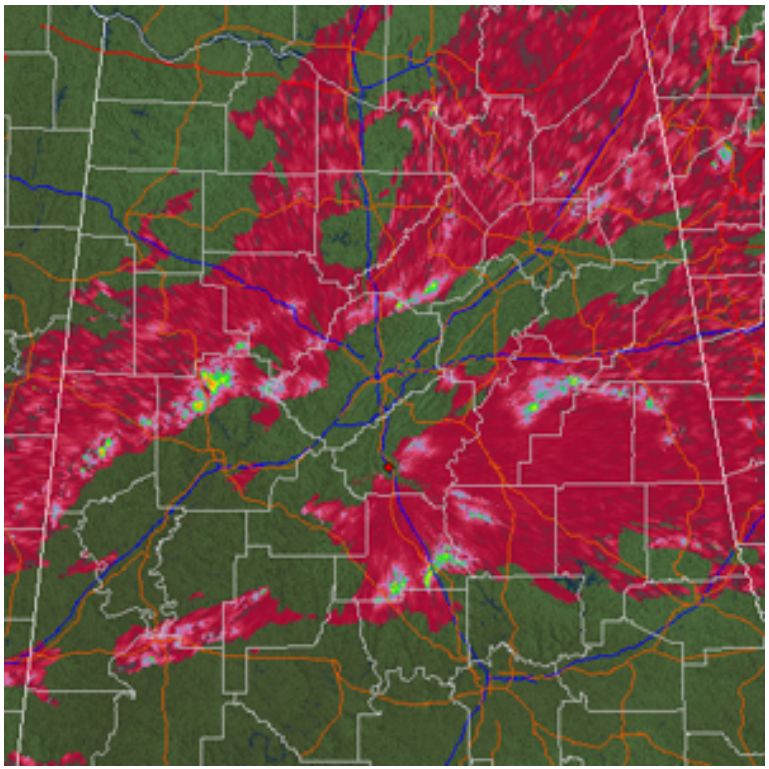

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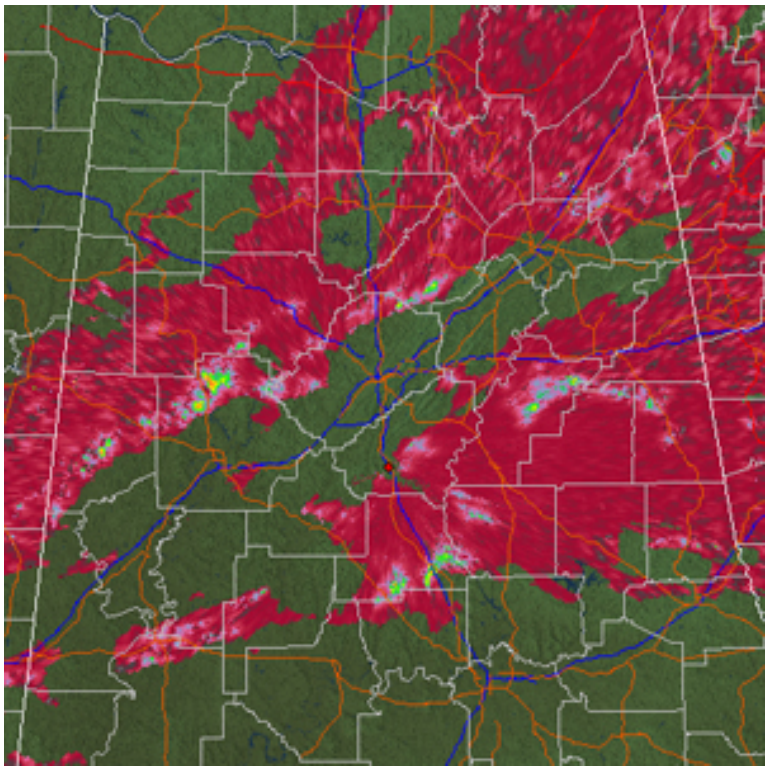

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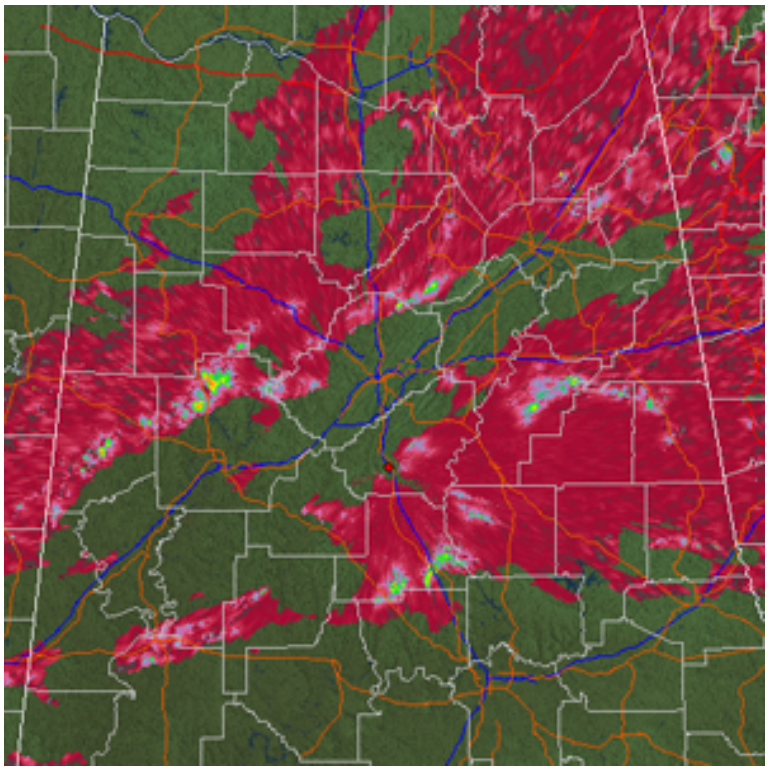

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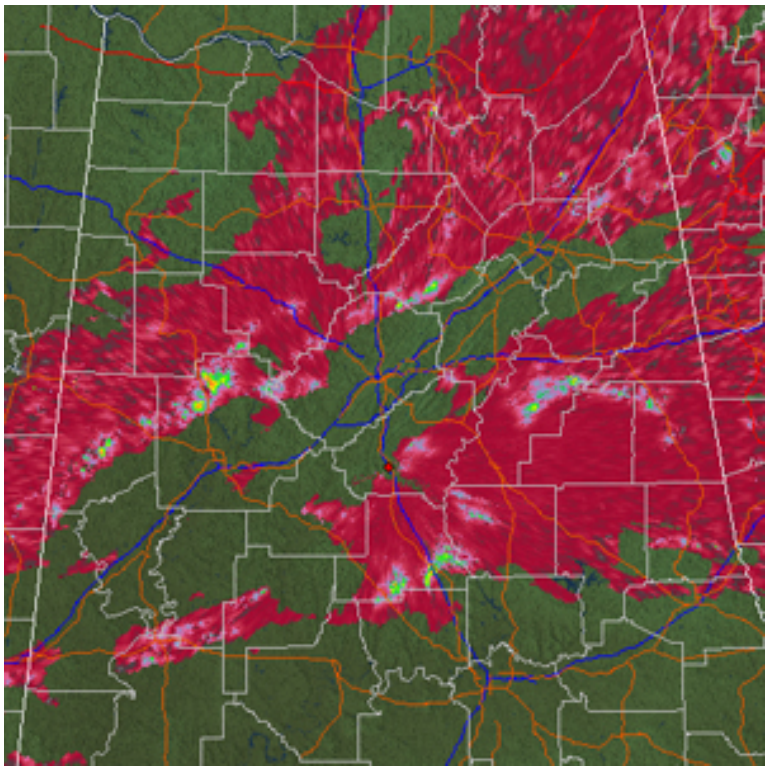
- K_{DP} = range derivative of Φ_{DP}

K_{DP}

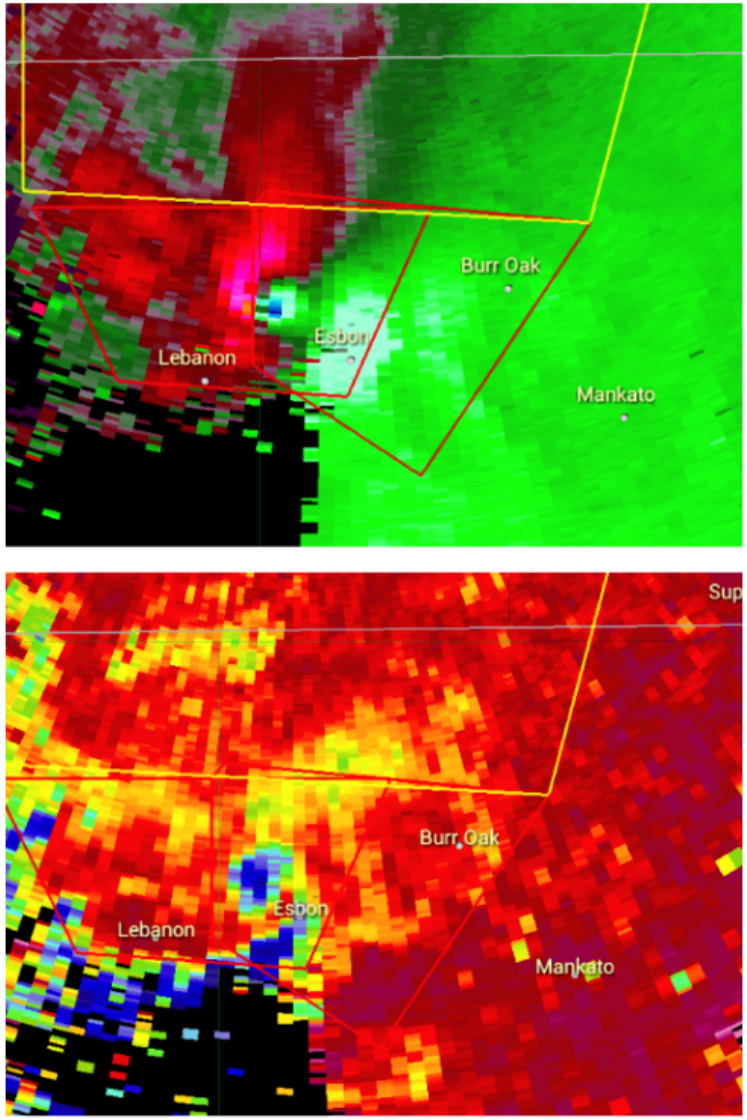


Polarimetric variables – ρ_{hv}

Co-polar correlation coefficient

$$\rho_{hv} = \frac{|\langle S_{hh} S_{vv} \rangle|}{\sqrt{\langle |S_{hh}|^2 \rangle \langle |S_{vv}|^2 \rangle}}$$

Tornadic Debris Signature



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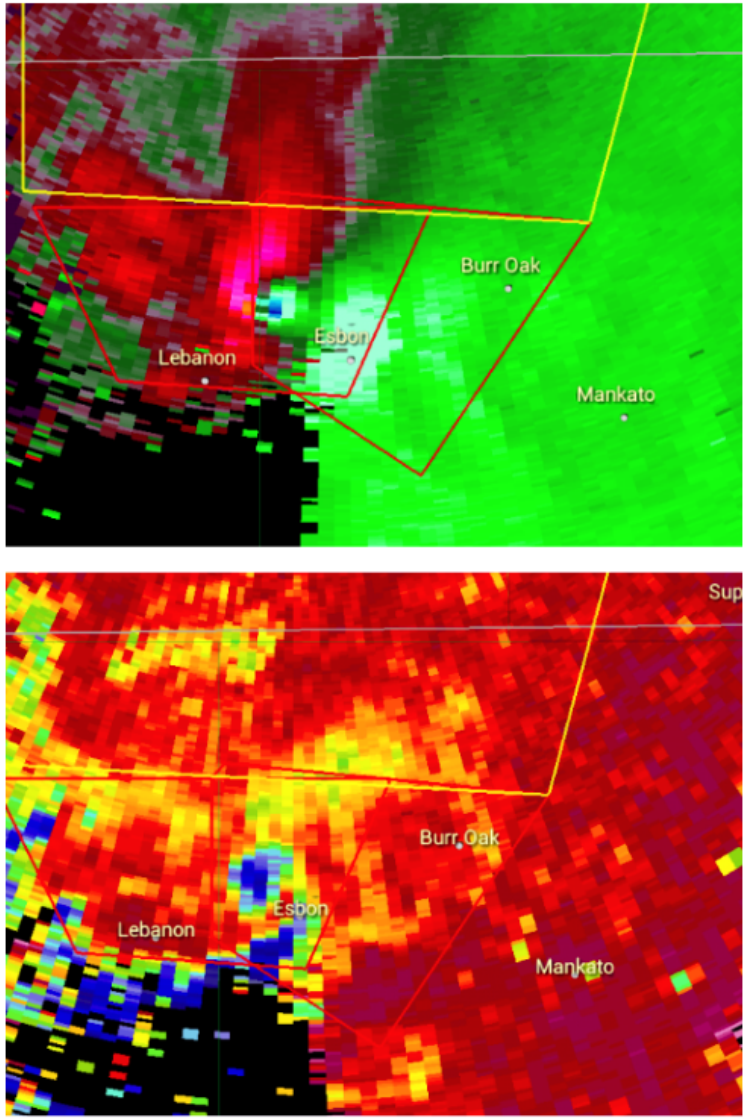

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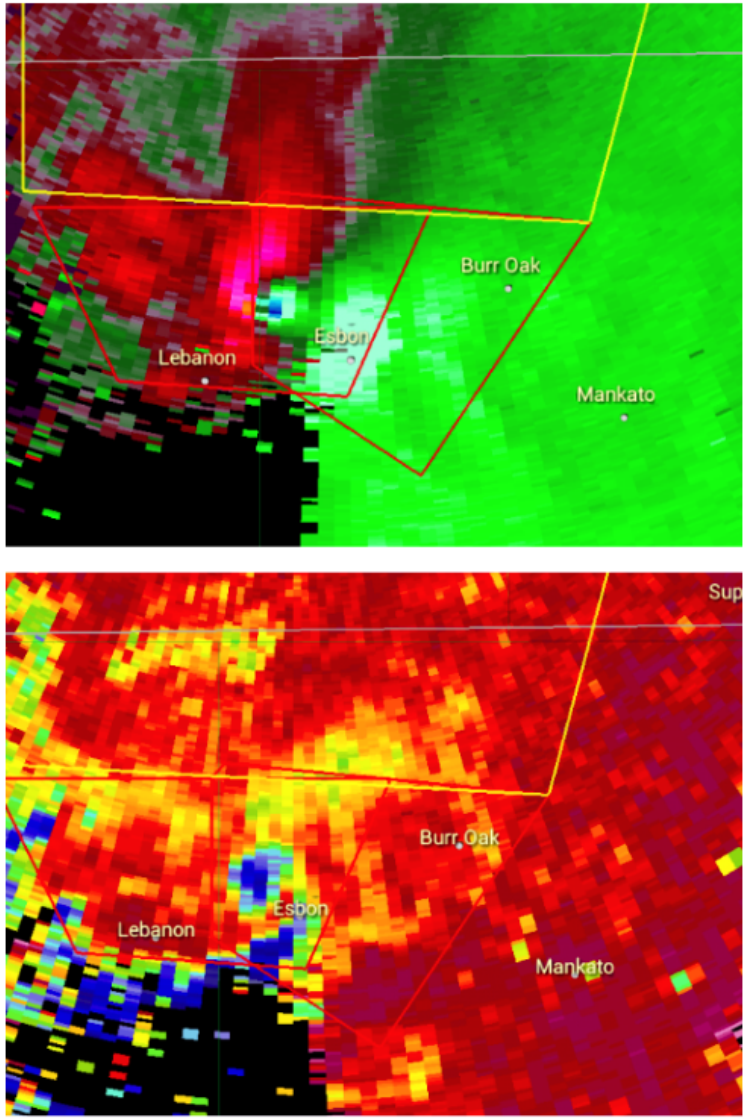

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- Can identify melting layer or tornadic debris

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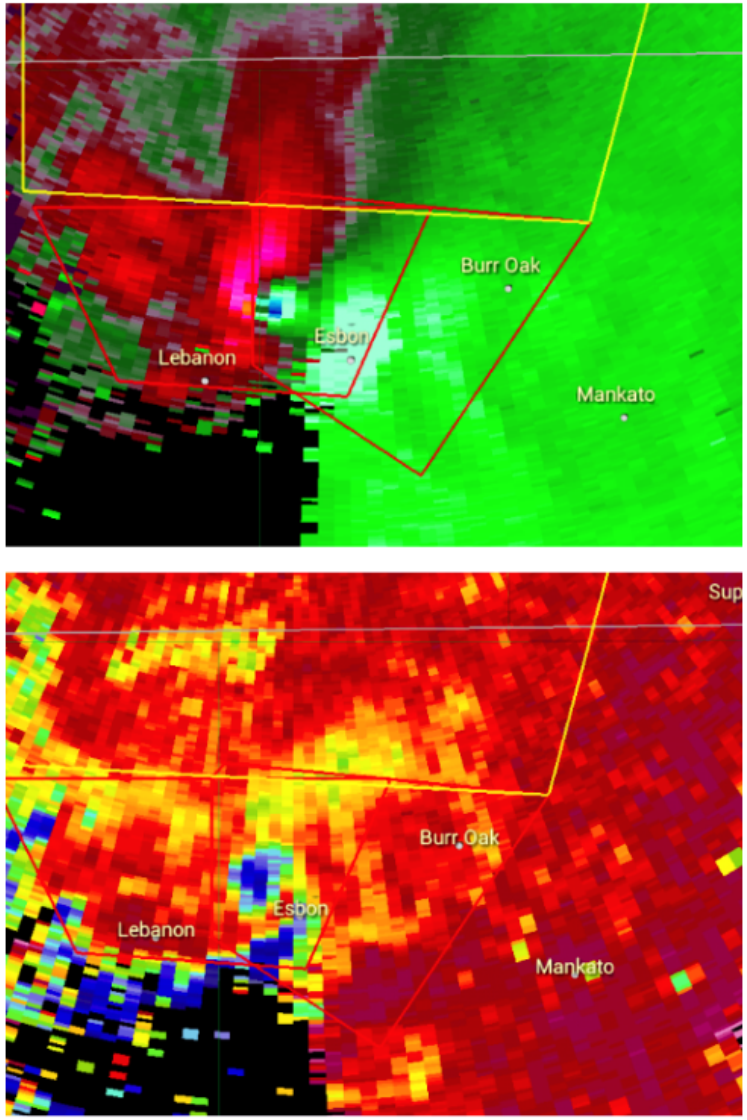

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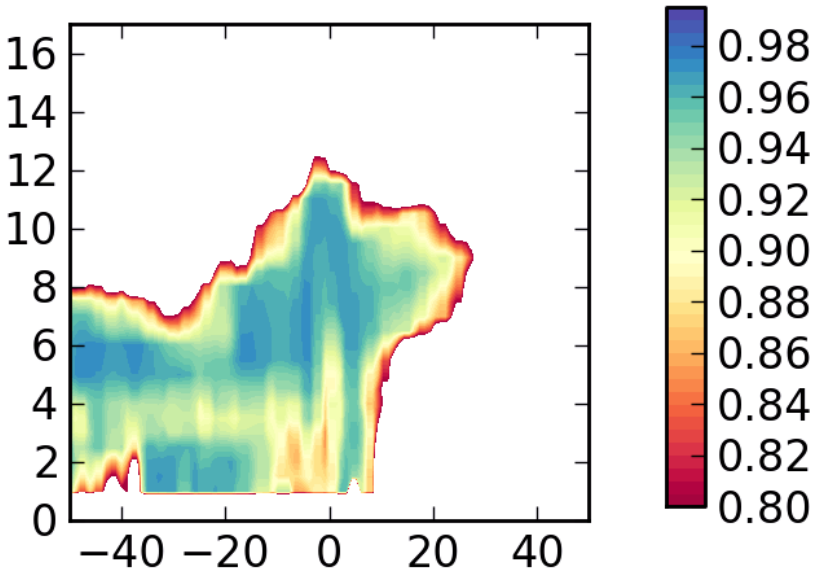
Melting level (appx 5 km)

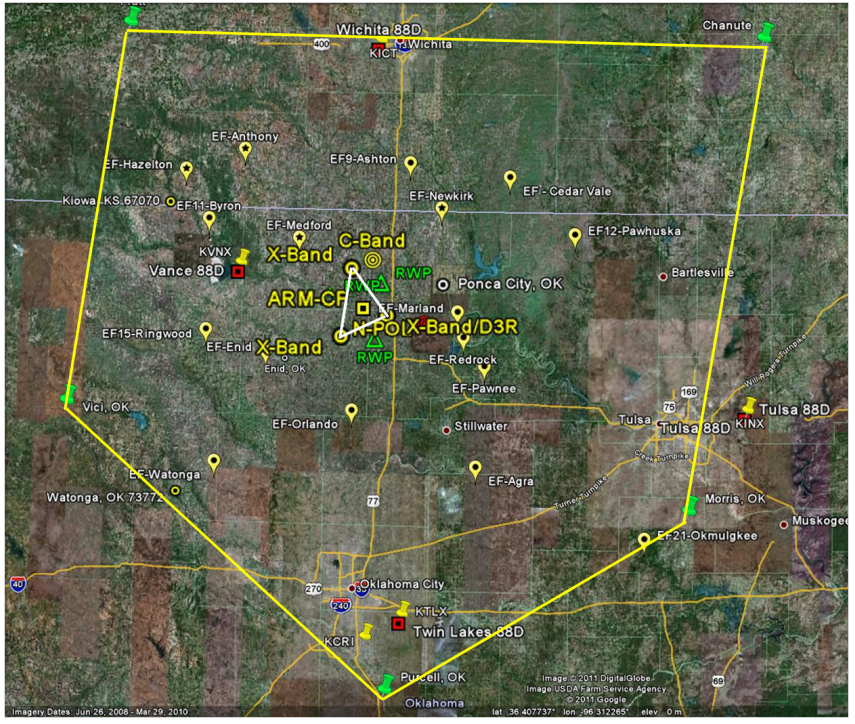


ARM MC3E

M

idlatitude Continental Convective Clouds Experiment

- April 22 – June 6 2011
- In and about ARM Southern Great Plains (SGP) site, Oklahoma (and Kansas)
- Science goals: improve understanding of deep convective systems to aid in parameterized representations



ARM MC3E

Data:

- KVNX (Vance, OK) WSR-88D S-Band dual-pol radar
- ARM C-band CSAPR radar (Lamont, OK)
- 3-Doppler wind retrievals (X-,X-,C-band) provided by K. North (McGill)
- High-resolution model simulations with bin and multi-moment bulk microphysics

Days investigated:

- April 25: Moderate MCS with heavy rain & large drops
- May 20: Strong, large MCS
- May 23: Very strong updrafts, supercell formation along dryline, hail
- May 24: Supercell formation along dryline, tornados reported, small hail

Science plan

Analyze strong updraft cores

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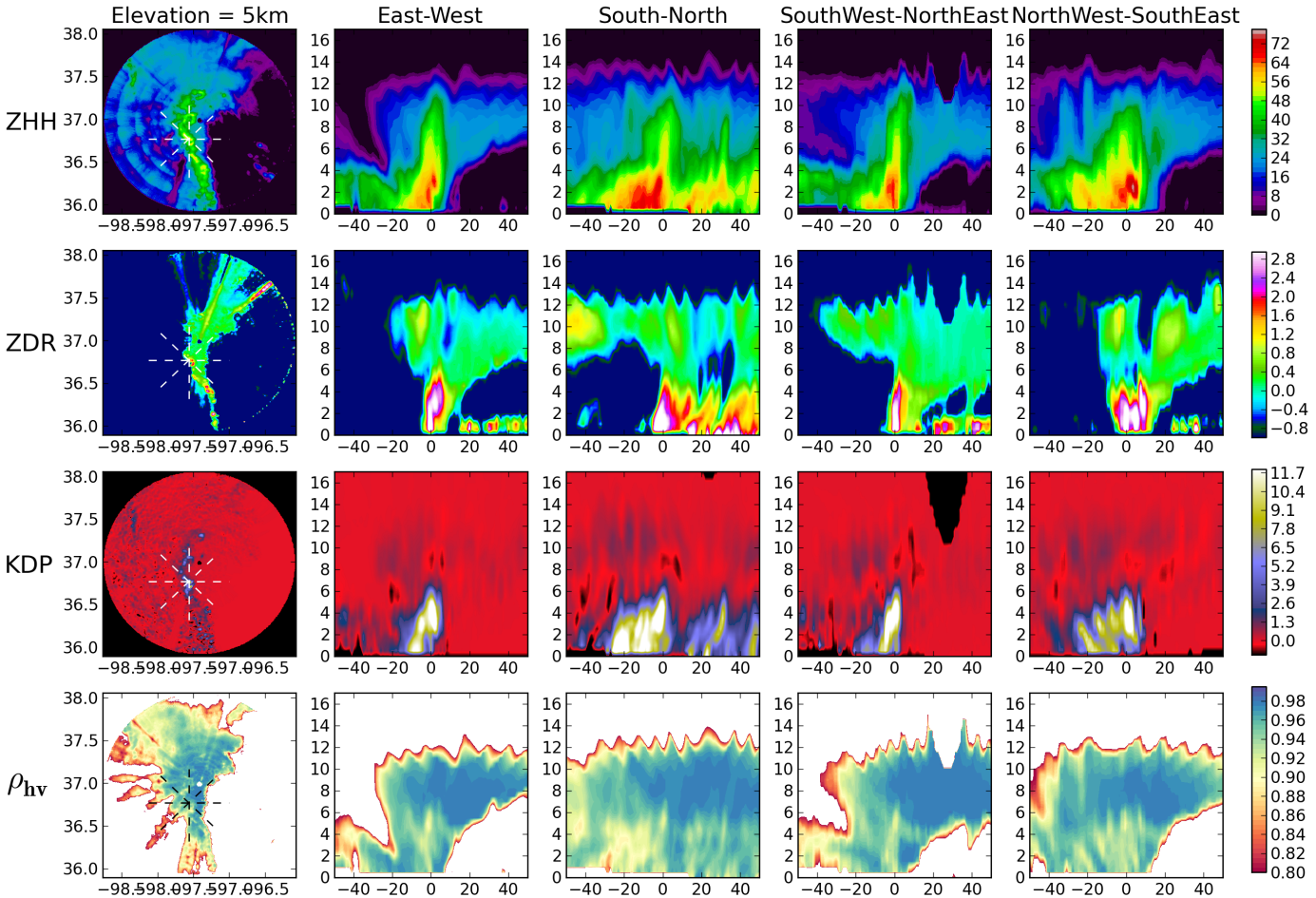
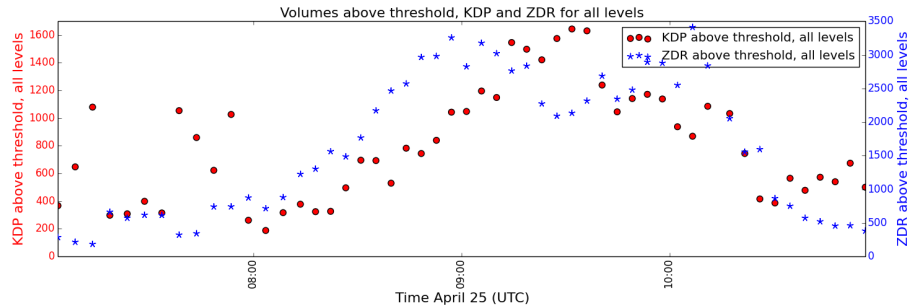
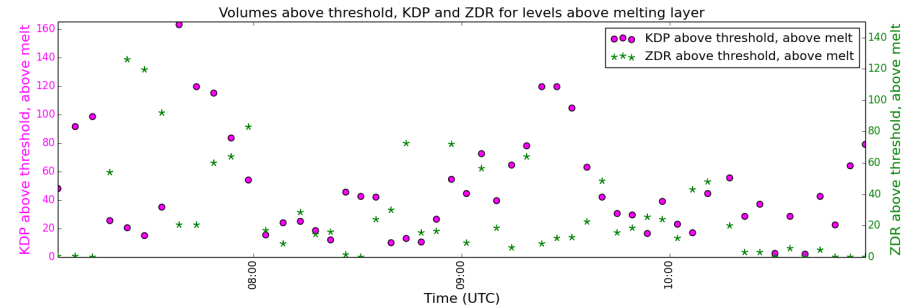
- Identify updrafts by KDP column
- Investigate relationship between polarimetric variables as well as with updraft strength
- Assess consistency/variability of observed patterns
- Identify observational targets for model constraint (vis-a-vis microphysics)

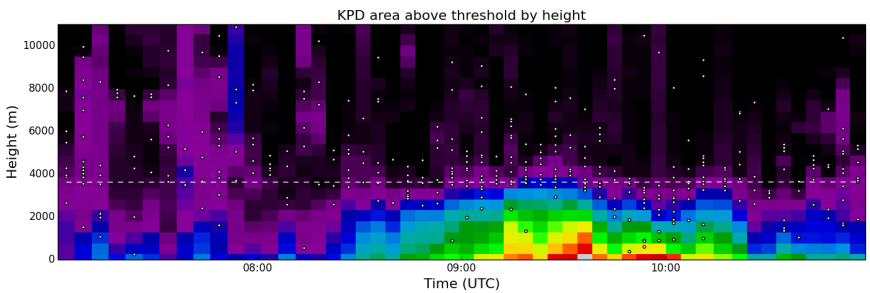
KDP & ZDR columns

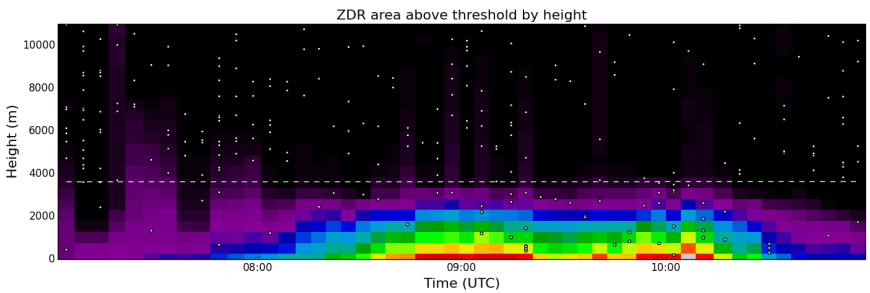


Bulk statistics on KDP and ZDR features, April 25

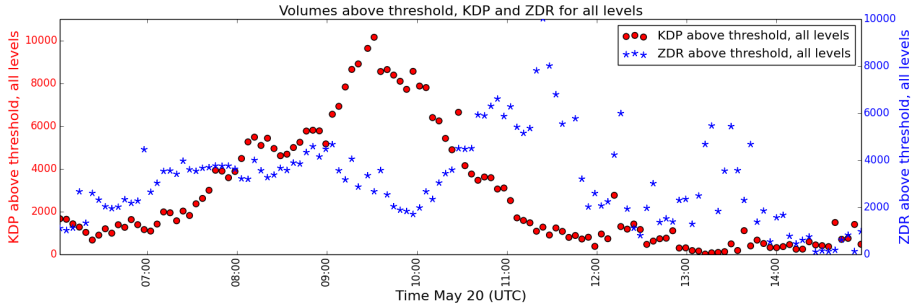


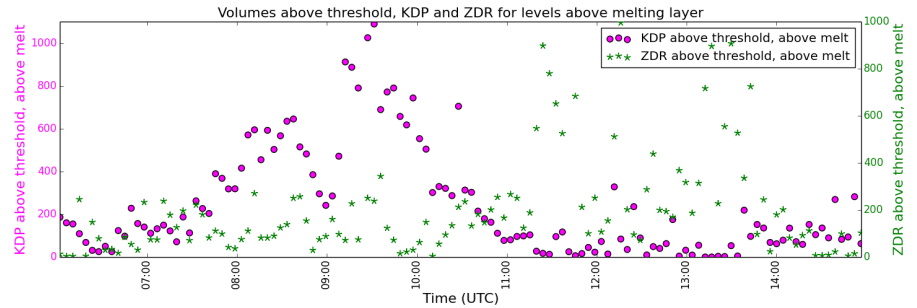


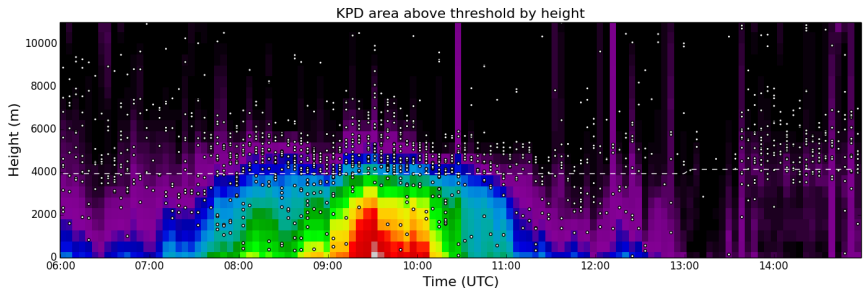


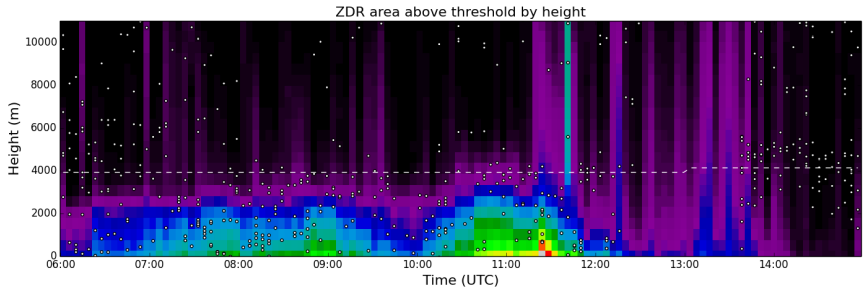


Bulk statistics on KDP and ZDR features, May 20









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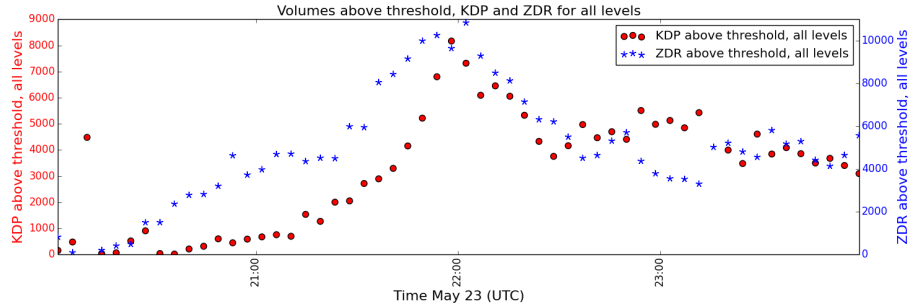
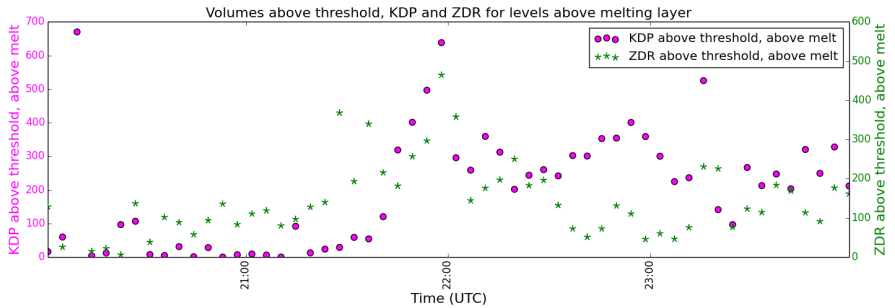
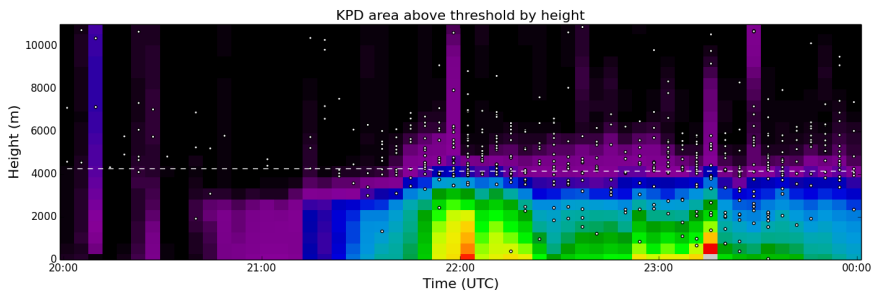
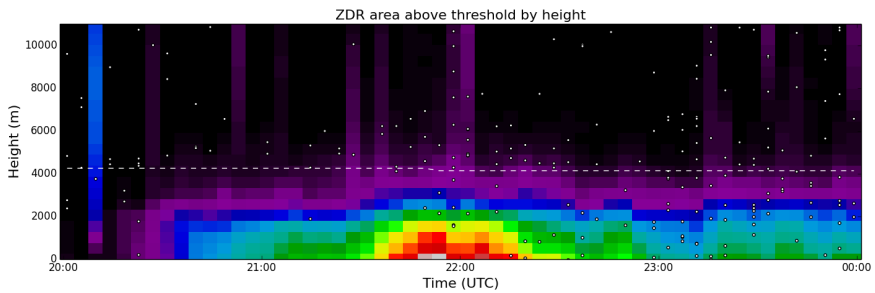
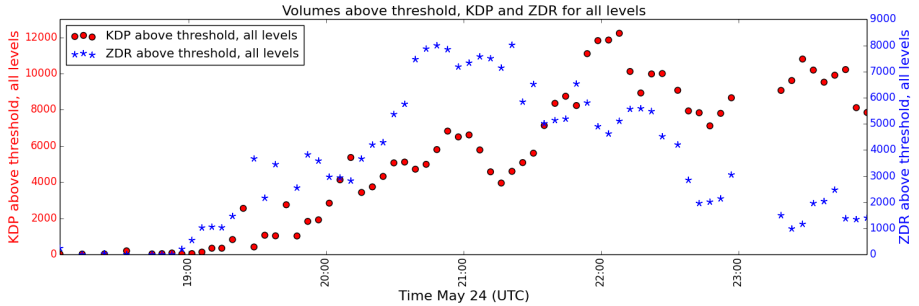


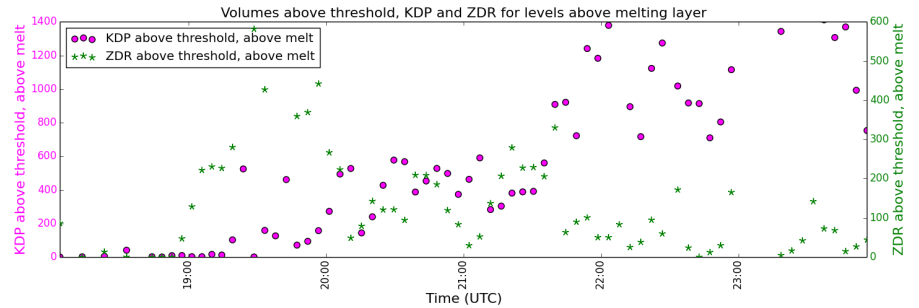


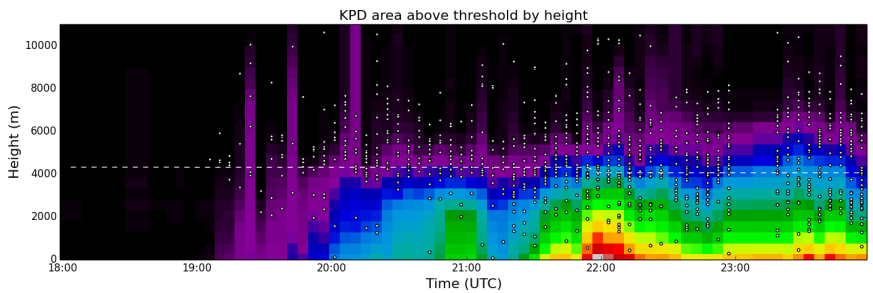


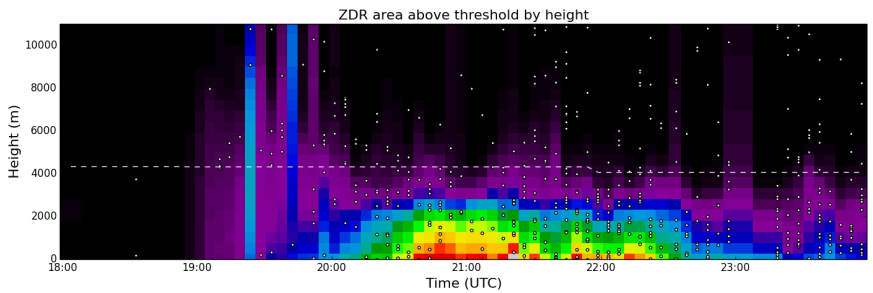


Bulk statistics on KDP and ZDR features, May 24



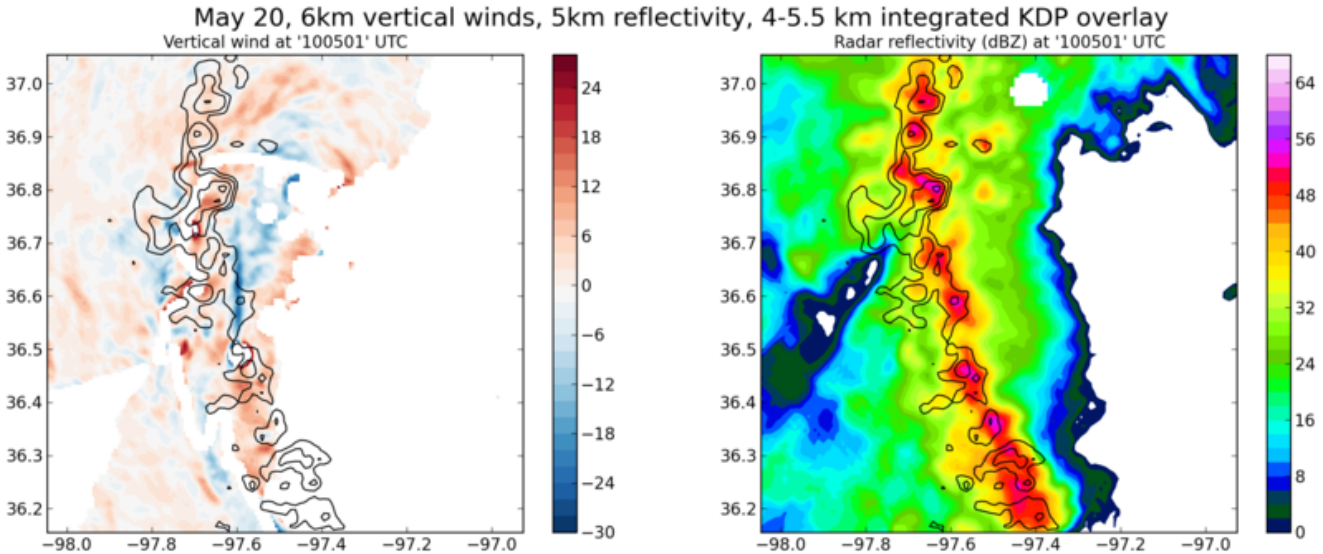






Correlation between updraft & KDP

Winds: 3-doppler retrieval (K. North); Contours: KDP; Reflectivity: CSAPR



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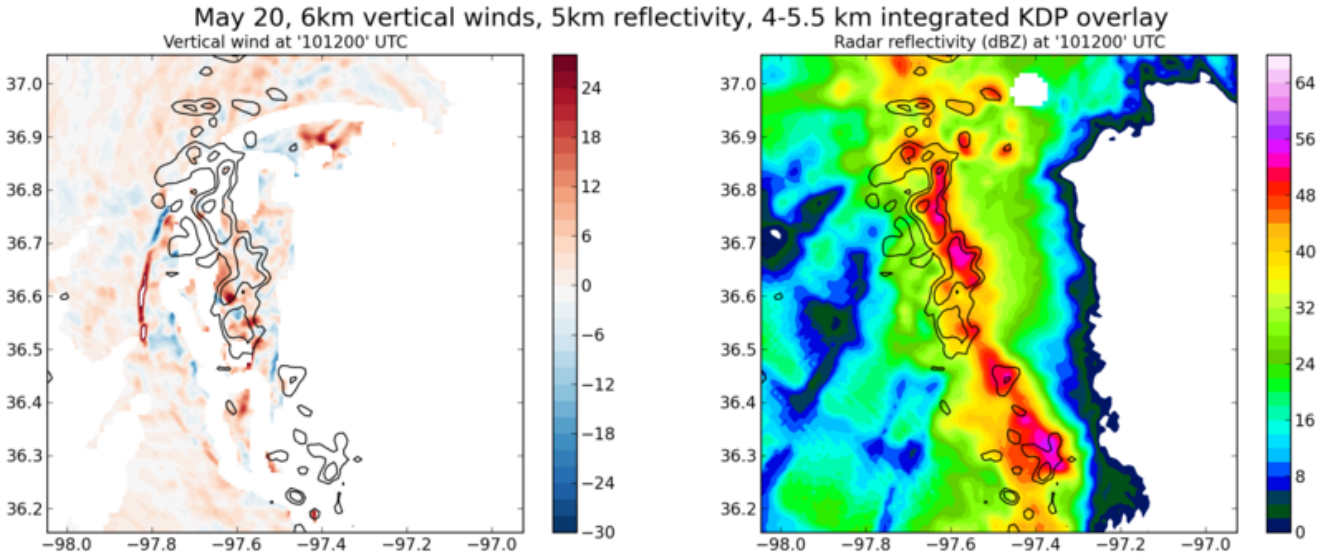
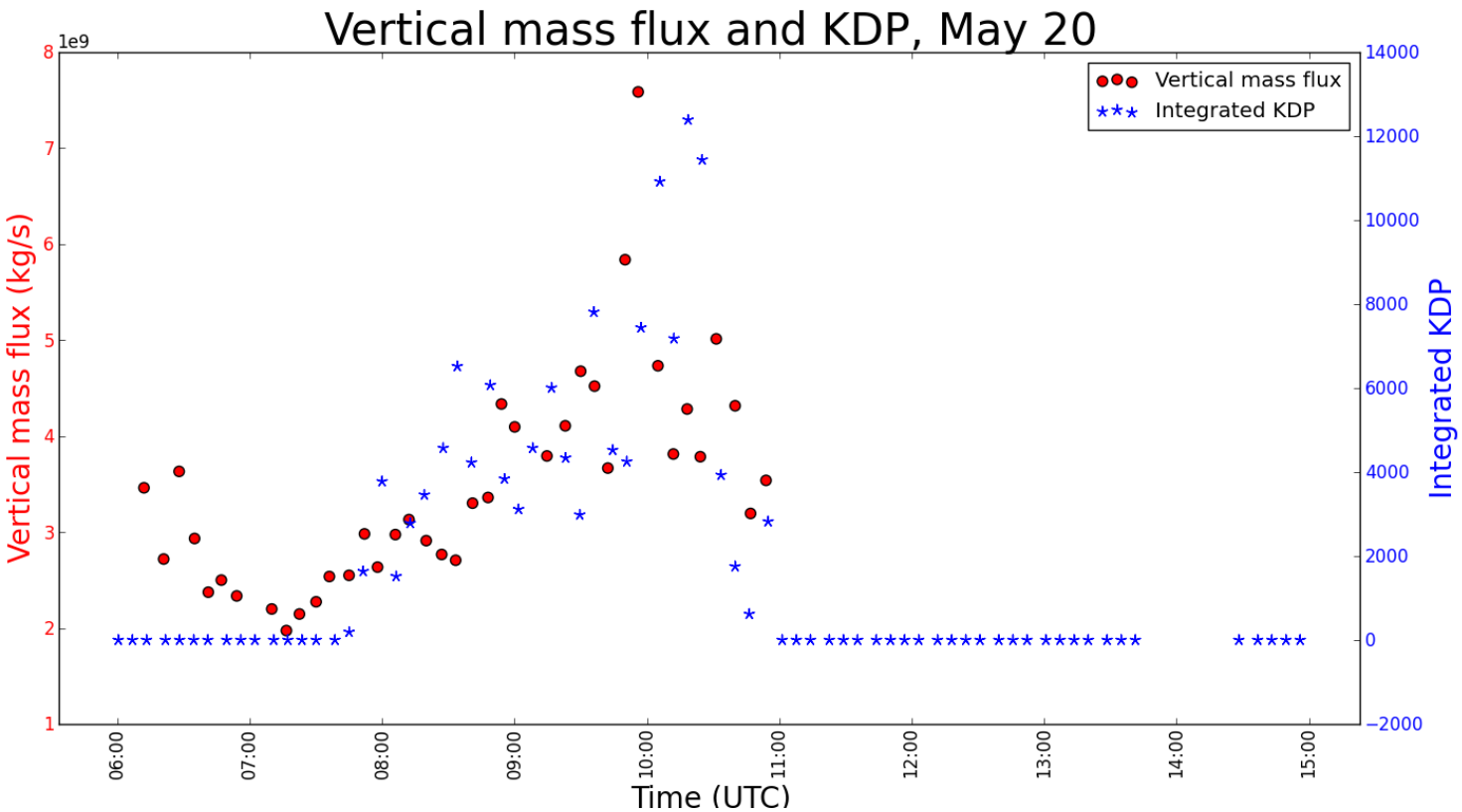
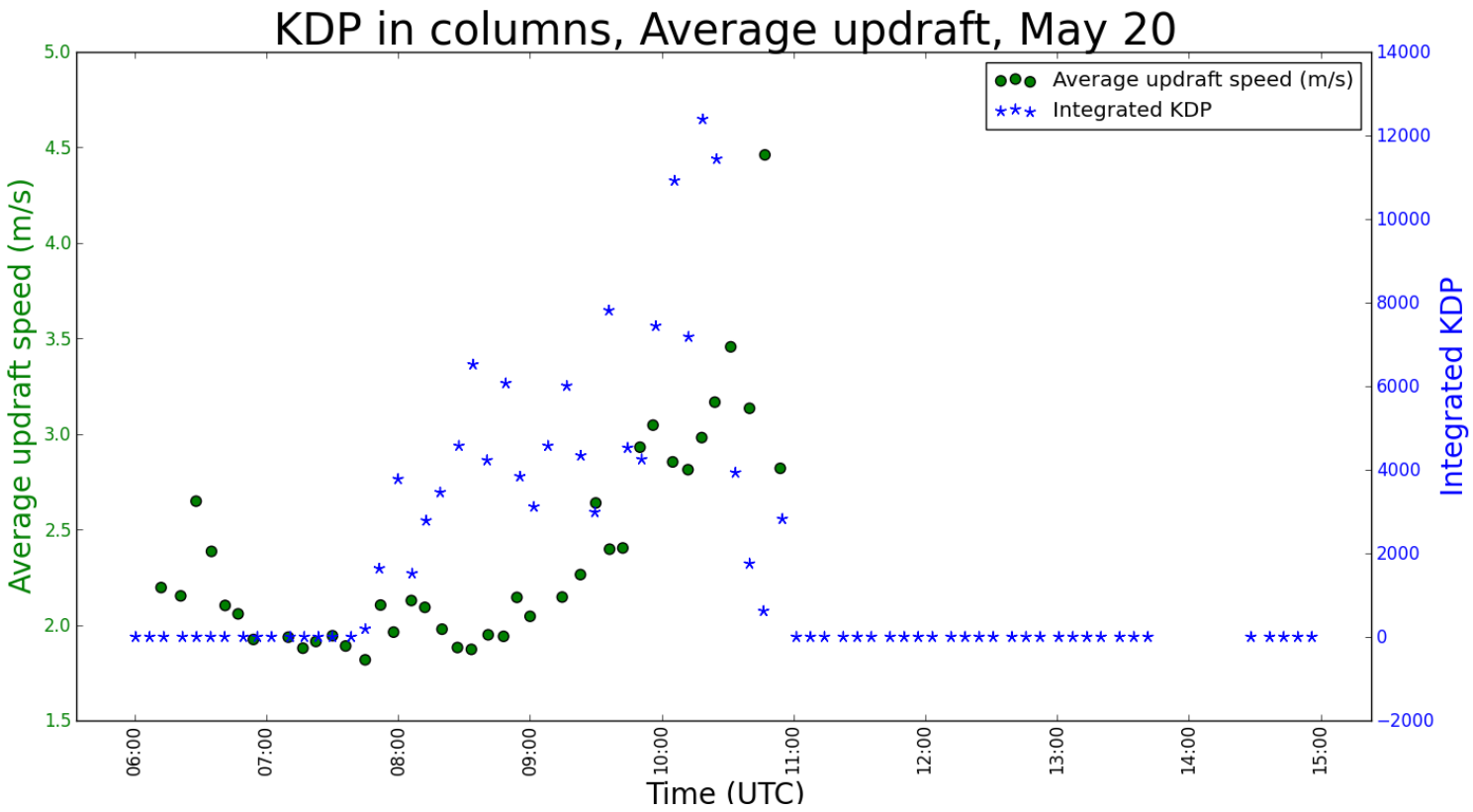


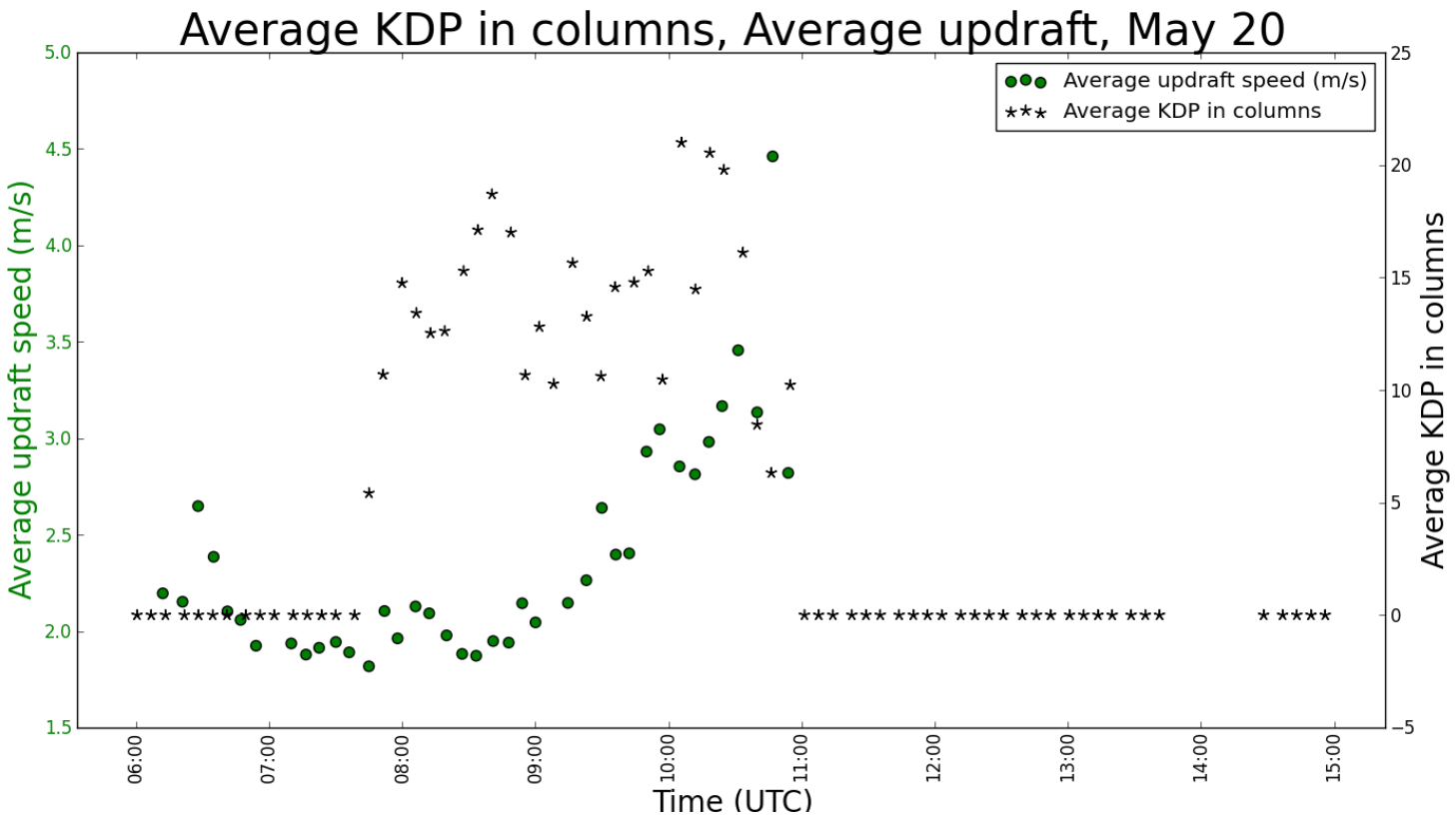
Vertical mass flux vs. KDP columns



Vertical mass flux vs. KDP columns



Vertical mass flux vs. KDP columns



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References I